

Application of Fuzzy Logic Theory to Risk Assessment in Oil and Gas Pipeline Projects

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Although there are many Risk Management Frameworks (RMFs) that could be used to manage the Risk Factors (RFs) in Oil and Gas Pipeline Projects (OGPPs), there are limitations in using them particularly, in the insecure and developing countries. This is mainly because of the unique nature of RFs in these countries. Additionally, there is little accessible information about RFs and the information are erroneous to analyze them properly. Therefore, this study aims to develop an integrated RMF, which identifies the RFs based on a comprehensive review of OGPPs worldwide. The RFs were evaluated via an industrywide questionnaire survey in Iraq. The fuzzy logic theory was used as a rational way of analyzing the impact of the RFs, in order to rank them in regards to their degree of impact on the pipelines. The fuzzy-based risk assessment model can reduce the uncertainty and the bias when analyzing the critical RFs using stakeholders' judgments and traditional risk index method. The results indicated that the most critical RFs are the third-party disruption risks, which are caused by companies or individuals but unrelated to the OGPPs. It is found that the most influential types of risks are the security and social RFs, the RFs related to the OGPP location, health and safety, and environment. The findings and recommendations of this paper and the developed risk management framework are more applicable to manage the OGPP RFs in Iraq and other countries that have similar circumstances.

Key Words: Oil and gas pipelines; risk management framework; fuzzy inference system; risk assessment; stakeholders' judgments.

Abbreviations

Abbreviation	Meaning	Abbreviation	Meaning	Abbreviation	Meaning
RMF	Risk Management Framework	RI	Risk Index	RS	Risk Severity
α	Cronbach's alpha coefficient	RFs	Risk Factors	VL	Very Low
OGPPs	Oil and Gas Pipeline Projects	S&S	Security and Social	L	Low
FLT	Fuzzy Logic Theory	PL	Pipeline Location	M	Moderate
RL	Risk Likelihood	R&R	Rules and Regulations	H	High
HSE	Health Safety and Environment	OC	Operational Constraints	VH	Very High

Introduction

Although Oil and Gas Pipeline Projects (OGPPs) provide a safe and economical mode of transportation for petroleum products (Hopkins *et al*., 1999), many Risk Factors (RFs) are threatening the safety of these projects, such as corrosion, planning, design and construction defects, natural hazards, operational errors, and mainly third-party disruption (Wan and Mita, 2010). Third-party disruption could be defined as any damage to a pipeline that is caused by an individual or group that not associated with the particular OGPPs (Guo *et al.*, 2018). For instance, surface loads that compress pipes, soil movement, natural phenomena, human activities near to a pipeline (Peng *et al*., 2016), terrorism, sabotage, theft, and cyber-attacks on control systems (Day, 1998 and Muhlbauer, 2004). Meanwhile, effective risk management for these RFs requires appropriate knowledge, up-to-date data (Balfe *et al.*, 2014), and accurate analysis of the RFs regarding their levels of likelihood and severity (Hopkins *et al*., 1999), in order to identify the critical risks. This is because dealing with each risk as the most critical RF results in a massive waste of resources (Srivastava and Gupta, 2010). However, due to the lack of truthful information and the poor documentation about the causes of incidents, the existing risk management methods are less effective in identifying the RFs in OGPPs in troubled and developing countries. Additionally, the inadequate information about the likelihood of third-party disruption risk means that the existing risk analysis methods are not accurate enough to analyze such risk (Ge *et al.,* 2015; Peng *et al*., 2016).

In such a situation, studies about evaluating the RFs in OGPPs are mainly based on reviewing the available documents about the incidents to identify the RFs that affect such projects. After this step, the judgments of the various stakeholders involved in the project are sought, using different types of surveys to analyze the impact of the RFs. Because the stakeholders have real experiences about the issues in their projects, this makes their opinions a valuable source to evaluate the likelihood and severity levels of the RFs (Sa'idi *et al*., 2014). Nevertheless, there is still uncertainty regarding analyzing the RFs using these methods because the stakeholders have different judgments of the likelihood and severity of these RFs (Lavasani *et al.*, 2011). The Fuzzy Logic Theory (FLT) is a mathematical tool that uses linguistics terms to analyze the RFs, in a situation where there are no sharp boundaries nor precise values of the likelihood and severity levels of the RFs. Additionally, the FLT can handle the uncertainty that results due to the lack of data and the personal evaluation of the stakeholders about the impact of the RFs (Biezma *et al*., 2018).

This study aims to develop an integrated Risk Management Framework (RMF) to provide a comprehensive approach to identify, analyze, and rank the RFs in OGPPs more holistically. This RMF will use the FLT as a rational way of analyzing and ranking the RFs in OGPPs by developing a computer-based risk assessment model using the Fuzzy Inference system (FIS) toolbox within MATLAB. This is to reduce the uncertainty and the biases that result from analyzing and ranking the RFs using the stakeholders' judgments and traditional risk index method. Such an RMF can provide appropriate and vast knowledge about the safety of OGPPs. Additionally, it can provide some of the essential data required for risk management in these projects, such as a list of the RFs that may threaten the projects, and the likelihood and the severity levels of such RFs. The next sections in this paper are the literature review, the methodology, the results of the study and the discussion.

Literature Review

Mubin and Mubin (2008) developed a risk management model that identifies and classifies the RFs in the gas pipeline projects in Pakistan. They used the Monte Carlo simulation method to simulate the RFs and provide recommendations for risk management in these projects. Schwarz and Sánchez (2015) proposed a risk management procedure to support decision-making processes in construction projects. They used experts' judgments and the artificial neural network technique to analyze the RFs and provide some recommendations to support the decision-makers regarding risk management. In these two models, the RFs were identified only from local review and during the construction stage of these projects. El-Abbasy *et al*. (2014) used a historical database and artificial neural network to predict the conditions of offshore oil and gas pipelines in Qatar and to prioritize the maintenance work for these pipelines. This study uses an available database to identify the RFs. Unfortunately, there is no such database available in developing countries, where the documentation is not in the best condition and there are no appropriate records about OGPP accidents. Moreover, these models have not tried to overcome the uncertainty that results from analyzing the RFs based only on the experts' judgments. Therefore, in order to develop a more integrated RMF, the developed framework must identify the RFs based on a comprehensive and worldwide view of the pipelines' RFs. Additionally; it addresses the RFs that affect the OGPPs during and after the construction. For example, third-party disruption, security and social risk, conflict over the land ownership, vehicle accident, the lack of data with regard to evaluating the RFs, and the similar type of RFs. In doing so, the developed RMF will be more applicable and suitable for managing the RFs in OGPPs in different countries and circumstances across the world.

Li and Guo (2016) classified the risk factors that affect the global investment in shale gas fields into economic, political, geological, technological, and internal RFs. Mubin and Mubin (2008) classified RFs in the gas pipeline projects in Pakistan during the construction stage into political, socio-economical, technical, organizational, natural catastrophe, financial, safety and security, and environmental RFs. El-Abbasy *et al.* (2014) classified the RFs that affect the gas pipeline in Qatar during the operational stage into physical RFs (e.g. pipes, age, diameter, metal loss, and coating conditions); operational RFs (e.g. corrosion, operating pressure, and flow rate); and external RFs (e.g. vehicle accidents, weather conditions, third-party disruption, and soil properties). This study aims to cover and classify all the types of the RFs that affect the general safety of OGPPs as far as possible, not just the economic, construction and operational challenges. The RFs in this study were classified into five different types depending on their characteristics: Security and Societal (S&S), Pipeline Location (PL), Health, Safety and Environment (HSE), Operational Constraints (OC), and Rules and Regulations (R&R) risks, see table 1. The identification and classification of the RFs is the first step in the developed RMF, as will be explained in the next section.

Research Methodology

Iraq has been chosen as the case study for this paper because its crude oil reserves are the world's 5th largest (E.I.A., 2015), and its gas reserves are ranging between the world's 10th to 13th largest reserves (I.E.A., 2013). Since 2003, there has been a high demand for more pipeline projects to meet the rapid increment in oil exports in Iraq (Jaffe, 2007). However, many RFs are affecting the OGPPs, which is hindering the oil export activities. The inadequate risk management in these projects due to the limited data about the RFs and their impacts on the pipelines is making pipeline failures inevitable. The methodology of this paper has followed a mixture of qualitative and quantitative research approaches. To do so, an integrated RMF is developed in this section. Figure 1 displays the procedure of the RMF of identifying the RFs using qualitative document analysis, and analyzing and modeling the RFs using stakeholders' judgments and the FLT, which is the quantitative part of the methodology.

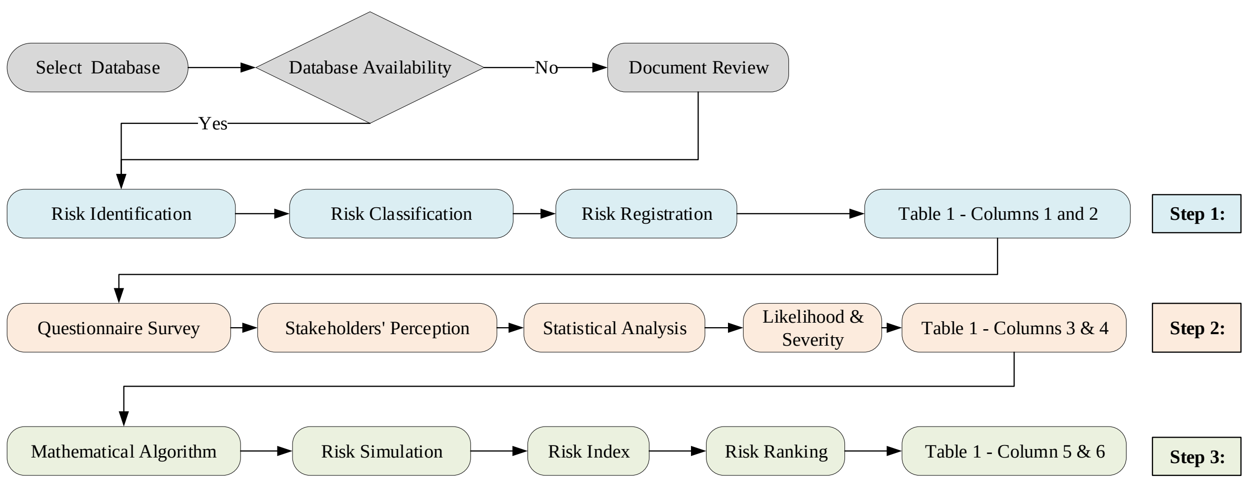

Figure 1: Risk Management Framework (RMF).

The RMF works in three steps as follows. **Step 1** concerns reviewing the available database(s) and studies to identify and classify the RFs in OGPPs (see table 1). This step could help in overcoming the problem of the scarcity of data about the RFs in OGPPs in Iraq. Deterministic approach and simulation are the two main ways, which is used to calculate the likelihood of failure. The deterministic approach utilizes the related data to assess the likelihood conditions of RFs, whilst the simulation approaches utilizes correlation analysis with the age and the conditions of the pipes to assess the likelihood of failure based on the historical records (Elsawah *et al*., 2016). As no available or accessible data could be used to identify the RFs in OGPPs in Iraq, such as reports about the pipeline accidents and the pipe conditions, **Step 2** explains the development of a questionnaire survey based on the findings from step 1. The purpose of the survey is to gather stakeholders' perceptions about the likelihood and severity levels of the RFs in order to provide the inputs for a computer-based risk simulation model, to be developed in step 3 to analyze the RFs. A pilot survey was conducted before distributing the questionnaire to check the clarity of the questions and the functionality of the questionnaire (Kraidi *et al*., 2018 c). The snowball data collection technique (Dragan and Alexandru, 2013) was used to ensure widespread distribution of the survey among stakeholders who have relevant experience in OGPPs in Iraq. The potential respondents were informed that the survey would be analyzed confidentially. In the survey, the likelihoods and the severity levels of the RFs were evaluated on a scale of 1= rare to 5= almost certain and 1= negligible to 5= catastrophic, respectively. Moreover, all identified RFs are classified under five types, which are S&S, PL, HSE, OC, and R&R RFs, to identify the degree of impact of each type on OGPPs. The participants were also asked to provide their views on whether aboveground or underground pipeline projects are the safer option. This questionnaire survey was sent to 400 potential participants, and the response rate was 49.5% with a total of 198 participants. **Step 3** is focused on developing a computer-based risk simulation model to analyze the RFs using the fuzzy inference system toolbox in MATLAB (Lavasani *et al.*, 2011 and Sa'idi *et al.*, 2014). As shown in figure 2, firstly, the fuzzy inference system was integrated with the Mamdani mathematical algorithm to define the membership functions for each RF to provide crisp fuzzification inputs for the model. The inputs are the Risk Likelihood (RL) and Risk Severity (RS) for each RF, calculated from the survey results. Secondly, the rules editor of the fuzzy inference system was used to define the rules controlling the behavior of the model. Finally, the centroid method of defuzzification was used to obtain the final outputs from the model, which were the Risk Index (RI) for each RF. The RFs are ranked based on their RI values, which judge both the likelihood and the severity levels for the RFs. The results of the questionnaire survey and the fuzzy inference system are discussed in the next section.

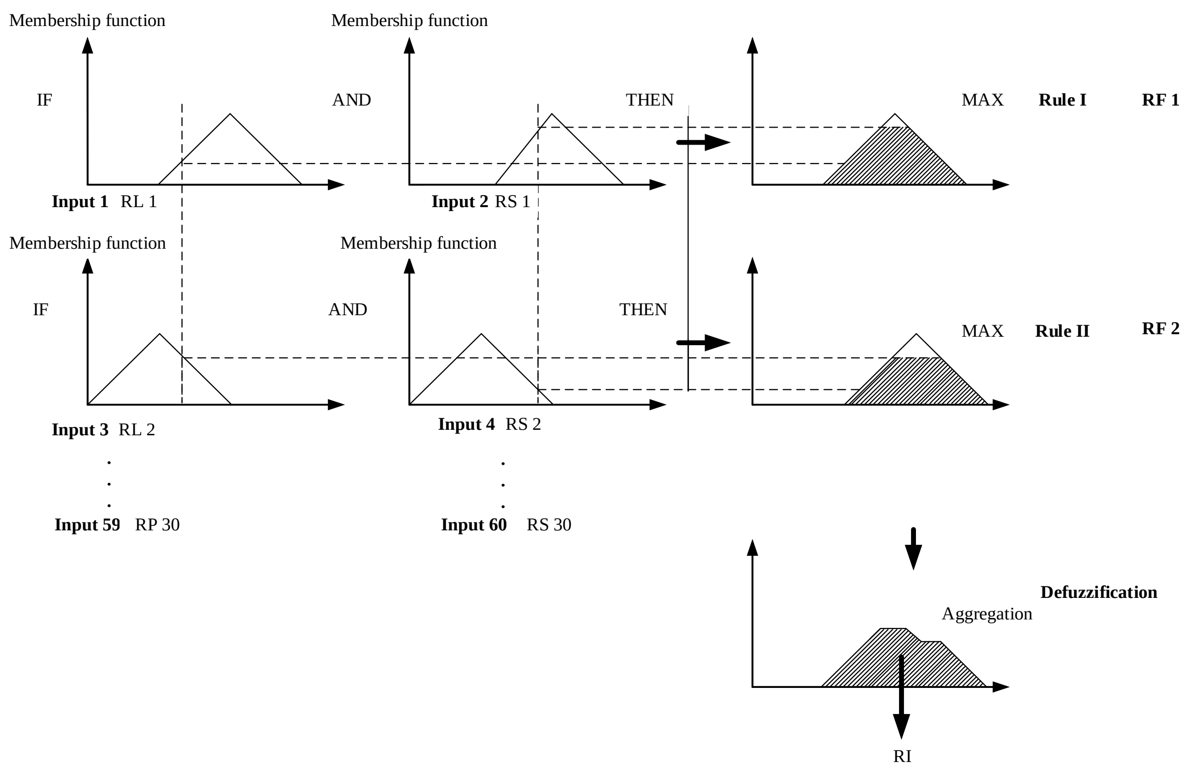

Figure 2: The Min-Max membership function of the fuzzy logic theory (Sa'idi *et al.*, 2014).

Results

Before analyzing the risk data, Cronbach's alpha correlation coefficient (α) was calculated to test the reliability level of the survey (Webb *et al.*, 2006), where a coefficient of 0.7 indicates a minimum level of reliability (Harvey, 2009). The α for the whole questionnaire was found to be 0.910, the α for the question about RL was found to be 0.919, and the α for the question about the RS was found to be 0.863.

Bennett and Nair (2010) and Nair (2013) suggested that an average response rate for an online surveys is about 30% to 36%, which means the response rate in this study is more than the expected rate. This rate is good compared to Okaro (2017), with a response rate of 33% and 82 participants, and Rowland (2010), with a response rate of 23% and 151 participants. According to the participants' occupations as recorded in the survey, 14 participants were consultants, planners or designers, 71 were members of construction teams, which means executive engineers, 41 were operators, 39 were owners or clients, and 33 were postgraduate students associated with OGPPs study. The students are employed in OGPPs and at the same time studying for their master's or PhD, which means they have experience of working on these projects. Some of the participants are either local or international engineers who are working for international OGPP companies in Iraq like British Petroleum, Gazprom, Shell, Samsung, and Petrofac However, due to data confidentiality, participants were not asked to provide the names of their organizations. In terms of participants' experience, 74 have less than five years of experience, 67 have five to 10 years, 29 participants have 10 to 15 years, and 28 of them have more than 15 years of experience. In respect of the participants' education, three of them were vocational or craftsmen, 28 have a high school or a diploma degree, 106 have a bachelor's degree, and 61 have a master's or a PhD degree. The reliability level of the survey and the appropriate sampling of the targeted population enhance the results of this study, because the survey was found to be reliable and all the categories of the stakeholders in OGPPs were represented in the survey.

Table 1

The results of identifying, classifying, analyzing, and ranking the RFs

RFs (Kraidi *et al.*, 2017; 2018 a, b and c)	**Type***	**Likelihood**	**Severity**	**Index**	**Rank**	**Risk Range****
Terrorism and sabotage	S&S	4	4.49	3.99	1	H
Corruption	R&R	3.98	4.32	3.87	2	H
Low public legal and moral awareness	S&S	3.71	4.15	3.80	3	H
Insecure areas	PL	3.72	4.19	3.76	4	H
Thieves	S&S	3.69	4.08	3.75	5	H
Corrosion and lack of protection against it	OC	3.69	3.99	3.72	6	H
Lack of proper training	R&R	3.65	3.85	3.71	7	H
Improper safety regulations	HSE	3.69	3.96	3.70	8	H
Exposed pipelines	HSE	3.67	3.95	3.70	9	H
Improper inspection and maintenance	HSE	3.66	3.9	3.69	10	H
Conflicts over land ownership	PL	3.5	3.65	3.68	11	H
Shortage of IT services and modern equipment	OC	3.67	3.92	3.68	12	H
Weak ability to identify and monitor the risks	OC	3.63	3.85	3.67	13	H
Design, construction and material defects	OC	3.33	3.61	3.64	14	H
Lack of risk registration	R&R	3.57	3.66	3.60	15	H
Easy access to pipeline	PL	3.63	3.77	3.57	16	H
Limited warning signs	HSE	3.63	3.73	3.56	17	H
Little research on this topic	R&R	3.62	3.7	3.55	18	H
Lawlessness	R&R	3.61	3.68	3.54	19	H
Stakeholders not paying proper attention	R&R	3.53	3.65	3.51	20	H
Public poverty and education level	S&S	3.5	3.61	3.49	21	H
Inadequate risk management	HSE	3.2	3.51	3.48	22	H
Leakage of sensitive information	S&S	2.98	3.4	3.38	23	H
Threats to staff	S&S	3.32	3.57	3.35	24	H
Operational errors	OC	3.10	3.41	3.30	25	H
Geological risks	PL	2.75	3.18	3.17	26	H
Natural disasters and weather conditions	HSE	2.65	3.07	3.10	27	H
Hacker attacks on the operating or control systems	OC	3.07	3.07	3.03	28	H
Vehicular accidents	PL	2.47	2.97	2.80	29	M
Animal accidents	PL	1.89	2.02	1.95	30	L

* S&S is Security and Social, PL is Pipeline Location, R&R is Rules and Regulations, OC is Operational Constraints and HSE is Health Safety and Environment. **Risk Range, Very Low (VL)= [0-1], Low (L)= [1-2], Moderate (M)= [2-3], High (H)= [3-4], and Very High (VH)= [4-5].

In the survey, there was a question asking respondents to compare the five types of RFs and rank them overall from 1 to 5 regarding their degree of impact on the OGPPs in Iraq, where: 1 means the highest risk factor and 5 means the lowest risk factor. The results were as follows: 1- S&S RFs with a total of 2.16, 2- PL RFs with a total of 2.63, 3- HSE RFs with a total of 3.11, 4- R&R RFs with a total of 3.55, and 5- OC RFs with a total of 3.55. The majority of participants (71%) agreed that extending the pipelines underground is a safer option than extending them above ground, even though they will be subject to corrosion, and there are added cost and time factors to consider when digging the trenches and laying the pipelines. This is because underground pipelines are not as easy to access as aboveground ones. Thus, they are less subject to terrorism and sabotage, thieves, and vehicular and animal accident RFs, which are the most influential risk factors in Iraq. In addition, there is no need for an early warning system of signs along with the pipelines when the pipes are underground.

Discussion and Conclusion

Identifying the RFs in OGPPs based on a wide-ranging review of the literature provides more appropriate knowledge about pipeline safety. Moreover, collecting information from various and trusted sources, which are government agencies, academic organizations, and professionals (e.g. consultants, planner, designers, operators, and researchers), provides real information for risk management in OGPPs in the future. This also ensures a more trusted analysis of RFs in these projects as the information has been gathered from field-experienced individuals. Collecting the stakeholders' perceptions about the RFs could reduce the time and the cost of investigations. However, this method depends on a willingness to cooperate with the researchers, which is one of the main disadvantages of this method.

The ranking of the RFs as shown in table 1 indicated that terrorism and sabotage, corruption, low public legal and moral awareness, insecure areas, and theft are the most critical RFs. In contrast, natural disasters and weather conditions, hacker attacks on the operating or control systems, and accidents involving vehicles and animals are the RFs with the lowest impact on OGPPs. In addition to the uncertainty that results from the stakeholders' judgment about the RL and RS levels, ranking the RFs using the traditional RI method as carried out in Kraidi *et al*. (2017; 2018 a and b) has some limitations. For example, an RF with a high value of RS could still be considered as a critical RF that needs to be dealt with as a matter of urgency. However, the same RF could not come at the top of the ranking if it had a low RL. This is similar if the RL of the RF is high and the RS is low, which is one of the RI method's limitations. When comparing the ranking of the RFs using the traditional RI method and the FLT, it was found that the five most critical RFs and the five less critical ones barely changed, with a slight change between the 3rd and the 4th and the 28th and the 29th RFs. The FLT assists in providing a more realistic ranking for the RFs as it is a powerful tool to overcome the uncertainty of the results when there is a lack of correct data and stakeholders' judgment, as explained earlier. In addition, the FLT also assists in overcoming the limitations in ranking the RFs using the traditional RI methods, because it has put the RFs having lower RL and RS values compared to the other RFs in a higher rank. For example, the likelihood of the RF 'little research on this topic' is = 3.62 and its severity = 3.7. The rank of this RF was 18th with RI = 3.55. However, the likelihood of the RF 'lack of risk registration' = 3.57 and its severity = 3.66, which are lower than the likelihood and severity levels of 'lack of risk registration', but 'lack of risk registration' was ranked higher as the 15th RF with RI = 3.6. The explanation of this ranking is because the FLT uses the If-Then rules that control the behavior of the risk assessment model. In addition to this, the FLT uses the class of linguistic summaries 'VL, L, M, H and VH' instead of the mathematical values of RI, as shown in table 1.

It was found from the survey that S&S is the most influential risk type, followed by PL, HSE, OC, and R&R. Such ranking says that the type of most critical RFs that affect the OGPPs in Iraq is different from other countries. For instance, it was found that OGPPs in European countries mainly suffer from mechanical failures and corrosion RFs (Tchórzewska-Cie´slak et al., 2018) because their pipelines are underground and they are less subject to sabotage RFs. The USA focuses more on the terrorism risk, especially after 9/11, in addition to corrosion because the USA uses underground pipelines as well (Rowland, 2010). African countries pay more attention toward theft risks because there is a strong black market for stolen products in these countries (Rowland, 2010). In addition, there is no available study about analyzing the RFs in OGPPs in Iraq (Kraidi et al., 2017; 2018 a, b and c). Therefore, it is difficult to compare the ranking of the RFs with other countries that have different types of RFs in their oil and gas pipeline projects.

Conclusion

In conclusion, the survey findings discovered that terrorism and sabotage, corruption, low public legal and moral awareness, insecure areas, thieves, and corrosion are the most critical risk factors, whereas natural disasters and weather conditions, hacker attacks on the operating or control systems, and vehicular and animal accidents are less critical RFs in OGPPs specifically in Iraq. This paper presents an integrated RMF using fuzzy logic theory to provide useful information about identifying and analyzing the RFs in a way that overcomes the problem of uncertainty and biased decisions that result from the inadequacy of raw data and stakeholders' judgment about them. The fuzzy logic theory provides an accurate analysis of the RFs in a situation when there are no sharp boundaries about their likelihood and severity levels. Moreover, the proposed RMF provides a comprehensive and systematic approach to risk management in OGPPs, which may be useful for companies or organizations that like to mitigate RFs in their projects, particularly in countries like Iraq. One of the limitations of this study is that it is not able to find relationships between the RFs and draw scenarios about failures in OGPPs. The developed decision-support tool is useful in analyzing the information about RFs and their RL and RS levels and rank them but it is not an automated ranking process. The future work will include automation and evaluation of the tool to optimize the risk mitigation methods and their degree of effectiveness in managing the RFs. In addition, the results of the study will be evaluated by conducting interviews with the experts in OGPPs and analyzing case studies in Iraq.

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References

Balfe, N., Leva, M. C., McAleer, B., and Rocke, M. (2014). Safety risk registers: challenges and guidance. *Chemical Engineering Transactions*. 36, 571-576.

Bennett, L., and Nair, C. S. (2010). A recipe for effective participation rates for web-based surveys, *Journal of Assessment and Evaluation in Higher Education*. 35(4), 357-365.

Day, N. B. (1998). *Pipeline Route Selection for Rural and Cross Country Pipelines*. (Vol. 46). Reston, Virginia: ASCE Publications.

Dragan, I.-M., and Alexandru, I-M. (2013). Snowball sampling completion. *Journal of Studies in Social Sciences*, 5(2).

Biezma, M. V., Agudo, D., Barron, G. (2018). A Fuzzy Logic method: Predicting pipeline external corrosion rate. *International Journal Press of Pressure Vessels and Piping*, 163(June) 55–62.

El-Abbasy, M. S., Senouci, A., Zayed, T., Mirahadi, F., and Parvizsedghy, L. (2014). Artificial neural network models for predicting condition of offshore oil and gas pipelines. *Automation in Construction*, 45, 50–65.

E.I.A. U.S. Energy Information Administration. (2015). Country Analysis Brief: Iraq, *U.S. Energy Information Administration*. URL https://www.eia.gov/beta/international/analysis_includes/countries_long/Iraq/iraq.pdf

Elsawah, H., Bakry, I., and Moselhi, O. (2016). Decision Support Model for Integrated Risk Assessment and Prioritization of Intervention Plans of Municipal Infrastructure. *Journal of Pipeline System Engineering and Practice*. 7(4), 04016010.

Ge, D., Lin, M., Yang, Y., Zhang, R. and Chou, Q. (2015). Reliability analysis of complex dynamic fault trees based on an adapted K.D. Heidtmann algorithm. *Journal of Risk and Reliability*. 229(6), 576-586.

Guo, Y., Meng, X., Wang, D., Meng, T., Liu, S., and He, R. (2016). Comprehensive risk evaluation of long-distance oil and gas transportation pipelines using a fuzzy Petri net model. *Journal of Natural Gas Science and Engineering, 33*, 18-29.

Guo, X., Zhang, L., Liang, W. and Haugen, S. (2018). Risk identification of third-party damage on oil and gas pipelines through the Bayesian network. *Journal of Loss Prevention in the Process Industries*, 54, pp. 163-178.

Harvey, K. L. (2009). SPSS Survival Manual: A step-by-step guide to data analysis using SPSS version 15. *Nurse Researcher*, *16*(3), 89-90.

Hopkins P., Fletcher R., Palmer-Jones R. (1999). A method for the monitoring and management of Pipeline risk - A Simple Pipeline Risk Audit (SPRA). *In 3rd Annual Conferences on Advances in Pipeline Technologies and Rehabilitation, Abu Dhabi* 44 (0), pp. 0–24.

I.E.A., International Energy Agency. (2013). World energy outlook special report. *France International Energy Agency*. URL https://www.iea.org/publications/freepublications/publication/WEO_2012_Iraq_Energy_OutlookFINAL.pdf
Jaffe, A. M. (2007). Iraq's oil sector: past, present and future. *James A. Baker III Institute for Public Policy and the Japan Petroleum Energy Center. Rice University*. URL http://large.stanford.edu/publications/power/references/baker/studies/noc/docs/NOC_Iraq_Jaffe.pdf
Lavasani, S. M., Yang, Z., Finlay, J., and Wang, J. (2011). Fuzzy risk assessment of oil and gas offshore wells. *Process Safety and Environmental Protection*, 89(5), 277-294.
Kraidi, L., Shah, R., Matipa, W., Borthwick, F. (2017). Analysing the Critical Risk Factors of Oil and Gas Pipeline Projects in Iraq. *In The Proceedings of the 3rd BUiD Doctoral Research Conference, British University in Dubai, the* 13th of May 2017, Dubai. pp. 133–148.
Kraidi, L., Shah, R., Matipa, W., Borthwick, F. (2018 a). An Analysis of the Critical Risk Factors in Oil and Gas Pipeline Projects Using a Comprehensive Risk Management Framework. *This paper was presented as a working paper at the ARCOM 34th Conference*, 3-5 September, Belfast, UK.
Kraidi, L., Shah, R., Matipa, W., & Borthwick, F. (2018b). Analyzing the critical risk factors in oil and gas pipelines projects regarding the perceptions of the stakeholders. In Creative Construction Conference 2018 - Proceedings Ljubljana, Slovenia.: Budapest University of Technology and Economics. pp. 304–311.
Kraidi, L., Shah, R., Matipa, W., & Borthwick, F. (2018c). The development of a questionnaire survey to investigate the critical risk factors in oil and gas pipelines projects. In Creative Construction Conference 2018 – Proceedings. Ljubljana, Slovenia: Budapest University of Technology and Economics. pp. 663–670.
Mubin, S., and Mubin, G. (2008). Risk analysis for construction and operation of gas pipeline projects in Pakistan. *Pakistan Journal of Engineering and Applied Sciences*, *2(Jan), 22-37.*
Muhlbauer, W. K. (2004). *Pipeline risk management manual: ideas, techniques, and resources*: Gulf Professional Publishing.
Nair, C. S. (2013). The Effect of Email Notification on Web-based Questionnaire Responses. *The Journal for Quality and Participation*. 35(4), 19.
Okaro, I.A. (2017). An integrated model for asset reliability, risk and production efficiency management in subsea oil and gas operations. *PhD thesis, School of Marine Science and Technology, Newcastle University, Newcastle, England, UK*.
Peng, X.-y., Yao, D.-c., Liang, G.-c., Yu, J.-s., and He, S. (2016). Overall reliability analysis on oil/gas pipeline under typical third-party actions based on fragility theory. *Journal of Natural Gas Science and Engineering, 34*, 993-1003.
Rowland, A. (2010). GIS-based prediction of pipeline third-party interference using hybrid multivariate statistical analysis. *PhD thesis, School of Marine Science and Technology, Newcastle University, Newcastle, England, UK*.
Sa'idi, E., Anvaripour, B., Jaderi, F., and Nabhani, N. (2014). Fuzzy risk modeling of process operations in the oil and gas refineries. *Journal of Loss Prevention in the Process Industries, 30*, 63-73.
Schwarz, J., Sandoval-Wong, J.A., and Sánchez, P.M. (2015). Implementation of artificial intelligence into risk management decision-making processes in construction projects. Chapter 29, 361-362.
Srivastava, A., Gupta, J.P. (2010). New methodologies for security risk assessment of oil and gas industry. *Process Safety and Environmental Protection*, 88(6), 407–412.
Tchórzewska-Cieślak, B., Pietrucha-Urbanik, K., Urbanik, M., and Rak, J. (2018). Approaches for Safety Analysis of Gas-Pipeline Functionality in Terms of Failure Occurrence: A Case Study. *Energies.* 11(6), 1589.
Wan, C., and Mita, A. (2010). Recognition of potential danger to buried pipelines based on sounds. *Structural Control and Health Monitoring, 17*(3), 317-337.
Webb, N. M., Shavelson, R. J., and Haertel, E. H. (2006). 4 Reliability Coefficients and Generalizability Theory. Journal *of Handbook of statistics, (26), 81-124.*